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Population Status of Brook Trout at Green Lake, Southeast Alaska, 1999

by

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Alaska Department of Fish and Game

Division of Sport Fish

Symbols and Abbreviations

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Weights and measures (metric)

Centimeter	cm
Deciliter	dL
Gram	g
Hectare	ha
Kilogram	kg
Kilometer	km
Liter	L
Meter	m
Metric ton	mt
Milliliter	ml
Millimeter	mm

Weights and measures (English)

cubic feet per second	ft^3/s
foot	ft
gallon	gal
inch	in
mile	mi
ounce	oz
pound	lb
quart	qt
yard	yd

Spell out acre and ton.

Time and temperature

day	d
degrees Celsius	°C
degrees Fahrenheit	°F
hour (spell out for 24-hour clock)	h
minute	min
second	s

Spell out year, month, and week.

Physics and chemistry

all atomic symbols	
alternating current	AC
ampere	A
calorie	cal
direct current	DC
hertz	Hz
Horsepower	hp
hydrogen ion activity	pH
parts per million	ppm
parts per thousand	ppt, ‰
volts	V
watts	W

General

All commonly accepted abbreviations.	e.g., Mr., Mrs., a.m., p.m., etc.
All commonly accepted professional titles.	e.g., Dr., Ph.D., R.N., etc.
and	&
at	@
Compass directions:	
east	E
North	N
South	S
west	W
Copyright	©
Corporate suffixes:	
Company	Co.
Corporation	Corp.
Incorporated	Inc.
Limited	Ltd.
et alii (and other people)	et al.
et cetera (and so forth)	Etc.
exempli gratia (for example)	e.g.,
id est (that is)	i.e.,
latitude or longitude	lat. or long.
monetary symbols (U.S.)	$, ¢
months (tables and figures): first three letters	Jan,...,Dec
number (before a number)	# (e.g., #10)
pounds (after a number)	# (e.g., 10#)
registered trademark	®
trademark	™
United States (adjective)	U.S.
United States of America (noun)	USA
U.S. state and District of Columbia abbreviations	Use two-letter abbreviations (e.g., AK, DC)

Mathematics, statistics, fisheries

Alternate hypothesis	H_A
Base of natural logarithm	e
Catch per unit effort	CPUE
Coefficient of variation	CV
Common test statistics	F, t, χ^2, etc.
Confidence interval	C.I.
Correlation coefficient	R (multiple)
Correlation coefficient	r (simple)
Covariance	cov
Degree (angular or temperature)	°
Degrees of freedom	df
Divided by	÷ or / (in equations)
Equals	=
Expected value	E
Fork length	FL
Greater than	>
Greater than or equal to	≥
Harvest per unit effort	HPUE
Less than	<
Less than or equal to	≤
Logarithm (natural)	ln
Logarithm (base 10)	log
Logarithm (specify base)	$\log_2$, etc.
Mideye-to-fork	MEF
Minute (angular)	'
Multiplied by	x
Not significant	NS
Null hypothesis	H_O
Percent	%
Probability	P
Probability of a type I error (rejection of the null hypothesis when true)	α
Probability of a type II error (acceptance of the null hypothesis when false)	β
Second (angular)	"
Standard deviation	SD
Standard error	SE
Standard length	SL
Total length	TL
Variance	Var

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ABSTRACT

An accidental introduction of 120,000 pen reared chinook salmon *Oncorhynchus tshawytscha* into Green Lake near Sitka, Alaska raised concern about possible impacts to the Green Lake brook trout *Salvelinus fontinalis* population, because potential interactions between these two species are not well understood. A study to estimate abundance and size composition of brook trout in Green Lake, using a two-event Petersen closed population estimator, was conducted in 1999 to provide information that may help evaluate impacts. An estimated 3,229 (SE = 900) brook trout ≥170 mm FL were present in Green Lake in 1999. We estimate that only 7% and 5%, respectively, of this population inhabited water deeper than 30 m and 35 m. Mean size of sampled fish was 250 mm FL (SE = 2 mm). Another population study should be conducted in 2002 to determine if the brook trout population has changed substantially since introduction of chinook salmon into Green Lake.

Key words: Alaska, Green Lake, brook trout, *Salvelinus fontinalis*, chinook salmon, *Oncorhynchus tshawytscha*, abundance, length composition, Petersen, mark-recapture.

INTRODUCTION

Concern developed over impacts to a brook trout *Salvelinus fontinalis* population in Green Lake near Sitka, Alaska, after nearly 120,000 lake-rearing hatchery chinook salmon *Oncorhynchus tshawytscha* escaped from net pens operated by Northern Southeast Regional Aquaculture Association (NSRAA) during June 1998 (B. Bachen, NSRAA, Sitka, personal communication). Shortly after the loss was discovered, NSRAA staff initiated a trapping effort in Green Lake to recapture as many chinook salmon from the lake as possible. From July 6 through October 10, 1998, 4,373 chinook salmon were recaptured, leaving about 116,000 in Green Lake.

Brook trout are not native to Southeast Alaska, but were introduced prior to statehood. According to unpublished records of Alaska Department of Fish and Game (ADF&G), between 1917 and 1989, brook trout were stocked in at least 62 locations in Southeast Alaska, including Green Lake. Most of these locations were stocked between 1926 and 1939, but plants also occurred in 1917, 1920, 1953, and 1989. Sources outside of Southeast Alaska, including Leadville, Colorado and Glennallen, Alaska, provided brook trout, but the Yes Bay hatchery at McDonald Lake in Southeast Alaska was the source for most systems now supporting brook trout populations. At least 22 known populations of brook trout inhabit Southeast Alaska lakes; several occur in more than one lake within multiple-lake systems (Appendix A1). Five lake populations (including the Green Lake population) occur in the Sitka area. Stocking records show an unknown number of brook trout were stocked in Green Lake in 1932.

Knowledge of the stock status of Southeast Alaska brook trout is limited to population studies in a few lakes. In 1976, brook trout abundance at Salmon Creek Reservoir near Juneau was estimated by ADF&G in response to public opposition to a sport bag limit reduction from 20 to 10 fish per day. A Schumacher-Eschmeyer mark-recapture model was used to estimate Salmon Creek Reservoir abundance of brook trout at 1,250 (95% CI = 1,042–1,562; Schmidt 1977). Winney (*unpublished*) used a Schnabel mark-recapture experiment to estimate abundance of brook trout in Thimbleberry Lake near Sitka at 487 fish (95% CI = 323–982). As part of a larger effort to evaluate several Ketchikan area lakes for recreational fishing opportunities, Hubartt (1990) attempted a mark-recapture estimate in 1989 at Perseverance Lake, but failed because of low catches. In general, these studies reported densities of 6 to 50 fish per surface acre.

Because the natural ranges of brook trout and chinook salmon are geographically separate, little is known about potential interactions between these species; however, interactions may be similar to those between cutthroat trout *O. clarki* and coho salmon *O. kisutch*. It is thought that juvenile coho salmon might compete with cutthroat trout for habitat and food as they overwinter in anadromous lakes or their inlet streams (Glova 1984). Additionally, coho salmon that do not smolt after their first winter in the lake might also compete year-round with cutthroat trout (Glova 1986). In contrast, larger cutthroat trout (>250 mm), which feed on rearing coho salmon, might benefit from their presence in the lake (Beauchamp et al. 1992).

In response to this issue, ADF&G and NSRAA jointly initiated a project in 1999 to assess the population status of brook trout in Green Lake. The goal of this project was to estimate abundance and length distribution of brook trout ≥170 mm fork length (FL) in Green Lake in 1999. Although introduced chinook salmon may have already impacted the brook trout population, we reasoned that this study would provide valuable data to help evaluate the impact of a large introduction of chinook salmon on the brook trout in Green Lake.

STUDY AREA

The Green Lake drainage, on Baranof Island, Southeast Alaska (Figure 1), empties into Silver Bay near Sitka. In 1979, the lake's surface area increased more than twofold when a hydroelectric dam was constructed at its outlet (Figure 2). Previously, the lake's surface area was 173.4 acres and its maximum depth was 26.3 m (Hoopes, *unpublished*). Hoopes projected the post-impoundment surface area and maximum depth to be 1,000 acres and 75 m when the lake was at normal reservoir elevation (119 m—the projected spill level of the dam). The normal reservoir elevation has been adjusted to 120.4 m since construction (B. Oman, City and Borough of Sitka, personal communication). Therefore, actual surface area may exceed 1,000 acres, with maximum depths of approximately 76 m at spill level. Since dam construction, the lake has surpassed spill level by >1 m for brief periods.

Hydropower demands and annual precipitation cycles combine to cause more extreme annual and seasonal fluctuations in the Green Lake surface elevation than those occurring in natural lakes that support brook trout in Southeast Alaska. Hoopes (*unpublished*) projected the minimum normal reservoir elevation, or the level below which power generation would cease, to be 85 m, and he projected that drawdowns of as much as 33 m would occur about once every 40 years. At an elevation of 85 m, the lake's surface area would be 400 acres. Between November 1998 and March 2000, lake levels never fell below 104 m elevation.

The brook trout population in Green Lake supports a small sport fishery. A 7-mile construction road built during dam construction provides foot access from the Sitka road system but is closed to vehicles. The lake can also be reached from Silver Bay by boat and a ½-mile hike, or by floatplane. Howe et al. (1998) estimated that only 80 brook trout were caught in the entire Sitka area during 1997. Fishing for brook trout in Southeast Alaska is allowed year-round; the bag and possession limit is 10 fish of any size.

In 1979, before lake impoundment, the population of brook trout ≥65 mm in Green Lake was estimated to be 1,442 fish (95% CI = 997–2,082; Hughes 1994). A limited post-impoundment study conducted during fall 1986 and spring 1987 (Arnold et al., *unpublished*) examined the spawning ecology of resident brook trout and limnological characteristics of the lake, and concluded that brook trout survived the initial flooding of the impoundment and successfully reproduced in the new reservoir. They also concluded that growth rates for age-2 and age-4 fish had increased, while growth rates for juveniles between ages 0 and 2 and adults between ages 4 and 5 had decreased since impoundment.

In 1998, approximately 450,000 chinook salmon were placed in net pens in Green Lake, to be reared from June through October and then transported to net pens in Bear Cove, to be reared in salt water until spring when they would be released. In 1999, 1 million chinook salmon were similarly reared and released, and NSRAA plans to rear and release 1 million chinook salmon annually.

METHODS

A mark-recapture experiment was used to estimate the abundance of brook trout ≥170 mm FL in Green Lake during summer 1999. This

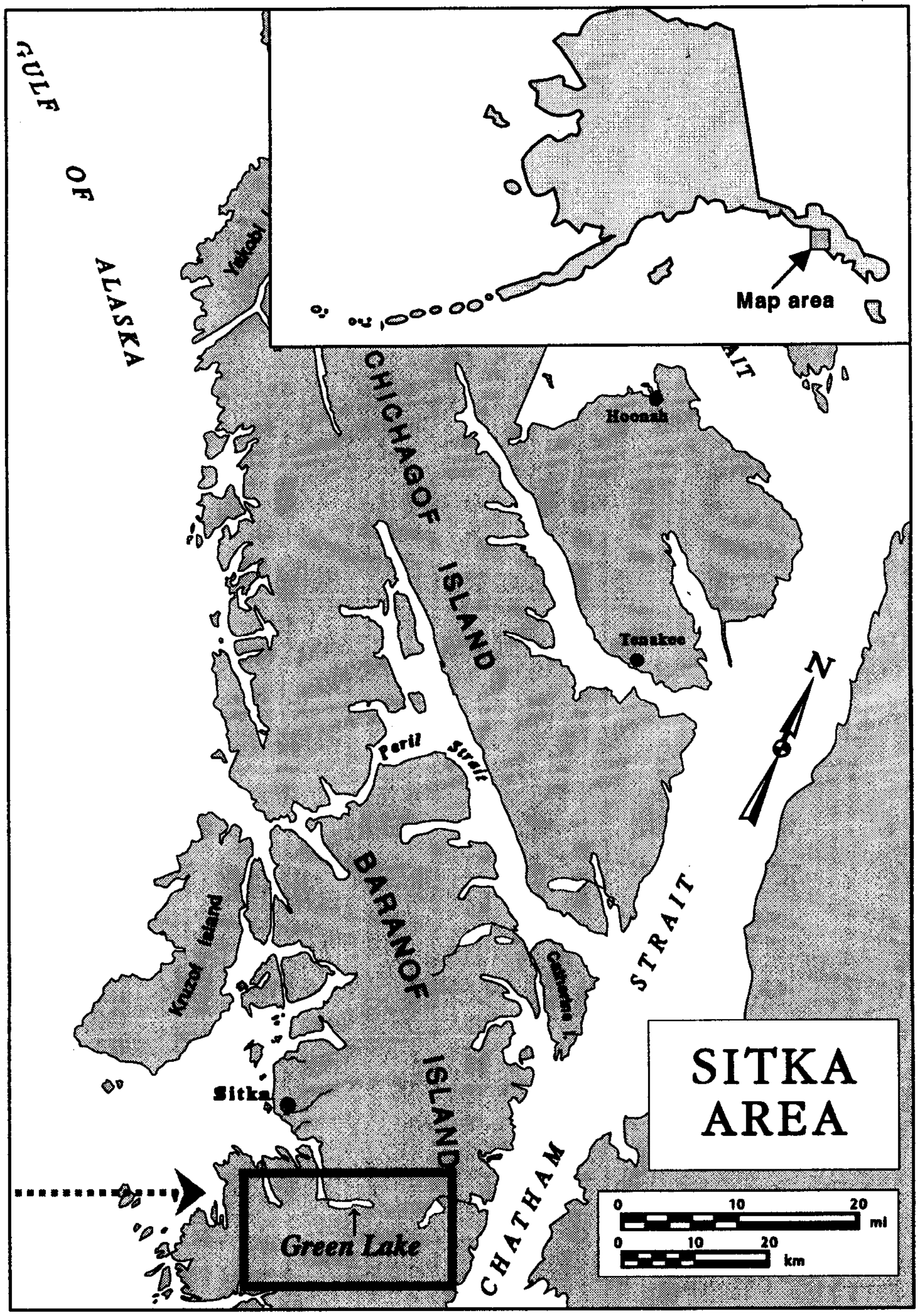

Figure 1.–Location of Green Lake, on Baranof Island, Southeast Alaska.

experiment was based on the Petersen closed population mark-recapture model (Seber 1982) and consisted of two 14-day events with a 10-day hiatus between events. Sampling occurred during July 16–July 29 (event 1) and August 9–August 22 (event 2).

We suspected that the probability of capture was different between shallow and deep areas because previous studies indicated that few freshwater fish reside in deep water (Benson 1961), and mark-recapture studies conducted for brook trout have reported higher catch rates in shallow (≤6 m)

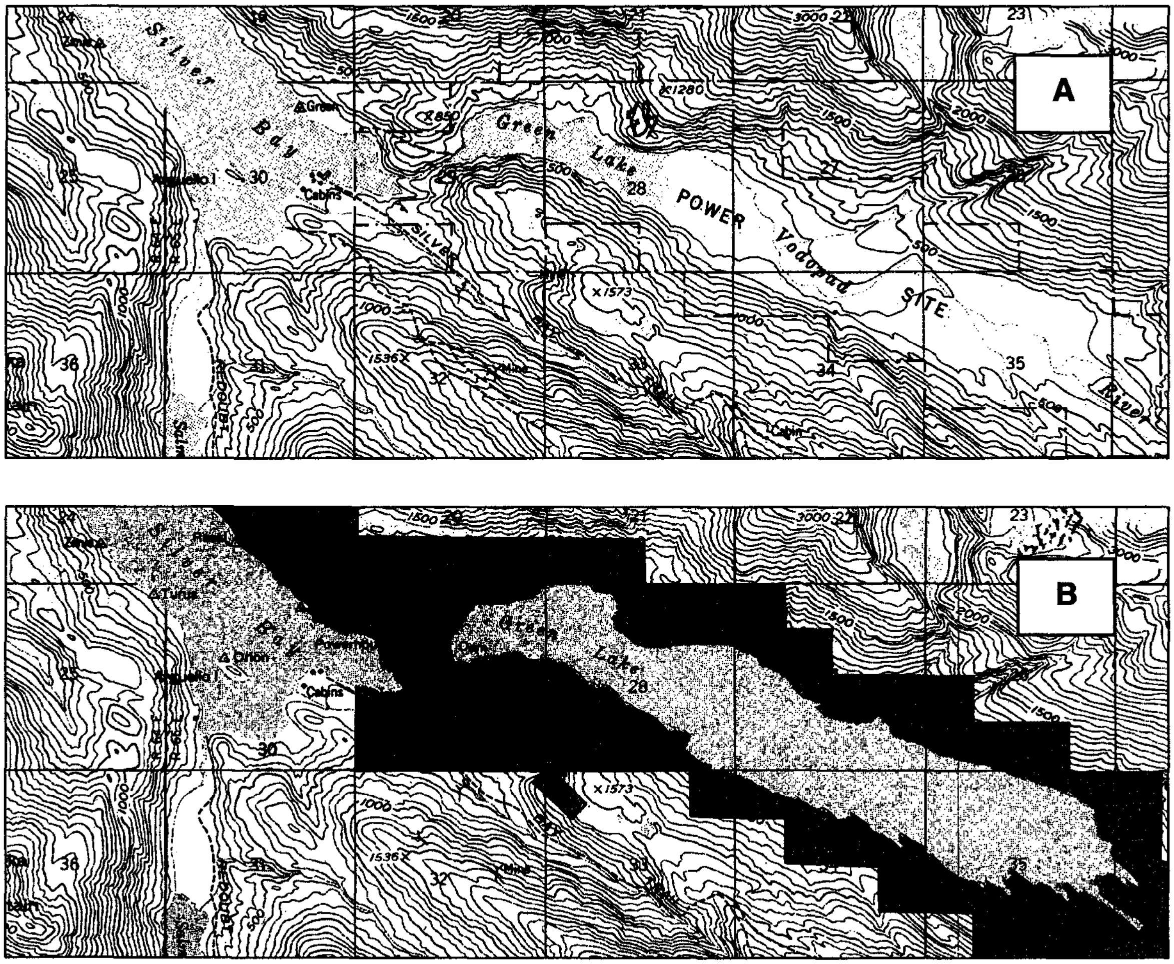

Figure 2.–Comparative sizes of Green Lake before (A) and after (B) impoundment.

waters (Schmidt 1977). Mark-recapture studies conducted by ADF&G for cutthroat trout in Southeast Alaska routinely exclude lake depths >35 m from sampling (Brookover et al. 1999). Because this study represented our first attempt at a mark-recapture experiment for brook trout in a deep (>30 m) lake, we designed the project to estimate abundance separately for fish inhabiting shallow and deepwater areas. We also designed the study to test the hypothesis that 5% or more of the population ≥170 mm FL was present in the deep water of Green Lake. This information could be used to support including or excluding deep areas from sampling in future studies.

We divided the lake into 14 areas (strata) of roughly equal size (Figure 3) to facilitate sampling, data recording, and evaluation of experimental assumptions. To ensure uniform effort throughout the lake, one stratum was fished per day, per event. The 14 strata were sampled consecutively, so that sampling in each event would proceed systematically from one end of the lake to the other and ensure equal probability of capture for all fish.

During each sampling day, 20 baited funnel traps were set in one stratum. Immediately prior to setting traps, placements were determined by randomly selecting 20 points within the stratum (Figure 4). Traps were set overnight on the lake bottom; trap depths were determined by fathometer. Hook-and-line sampling was done by casting or trolling a variety of small lures (i.e., spinners, small spoons, and other artificial lures), with and without bait (i.e., shrimp), from a boat

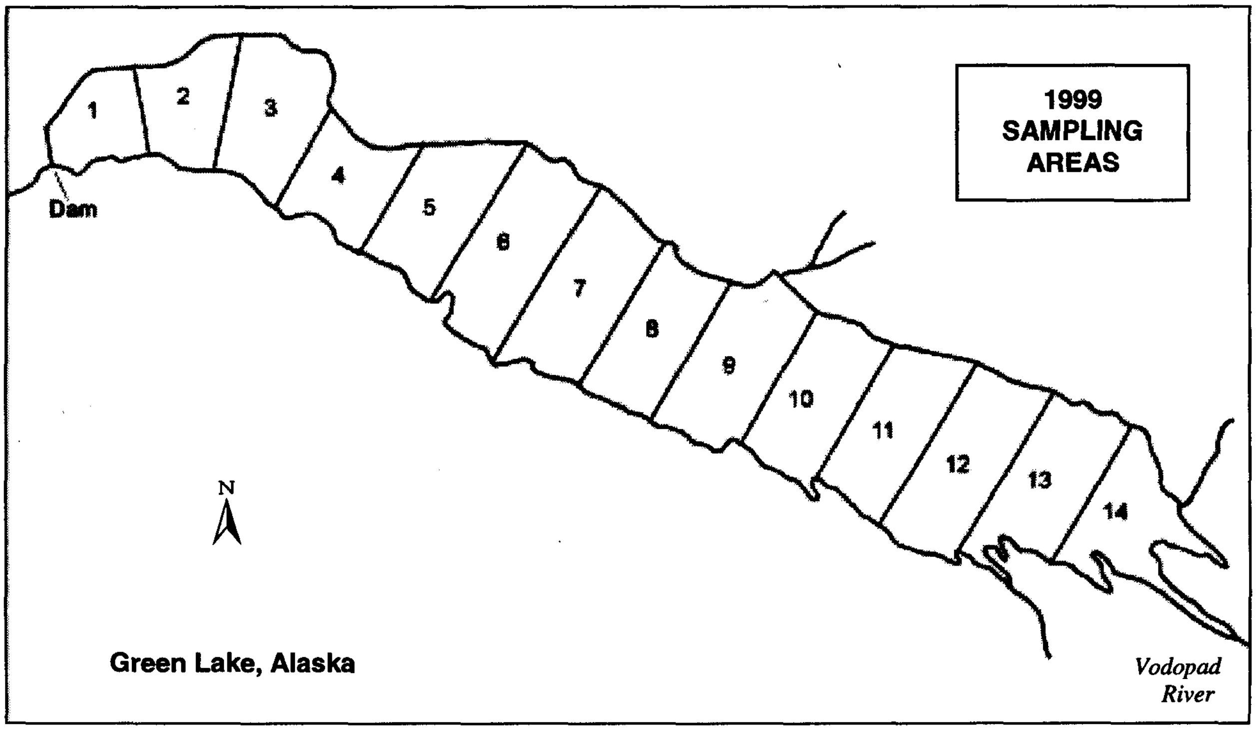

Figure 3.–Sampling areas (1–14) at Green Lake, Baranof Island, Alaska, in 1999.

where depth was ≤5 m (i.e., shoreline). Hook-and-line effort was uniformly distributed along the lake perimeter by fishing an equal number of rod-hours in each stratum and sampling the entire shoreline within each stratum.

Funnel traps 1 m long and 0.6 m in diameter, with a single 5-cm diameter opening at each end, were constructed from two metal hoops and ¼-inch (6-mm) Vexar mesh. About 300 ml of salmon eggs, disinfected for 15 minutes in a 1% Betadyne solution, were suspended in a perforated bait container within each trap.

All captured brook trout were examined for marks and measured to the nearest millimeter fork length. All unmarked fish ≥170 mm FL were tagged with a uniquely numbered T-bar (Floy®) tag, given a secondary mark to permit estimation of tag loss, and released as near as possible to their location of capture. Tags were inserted on the left side of the fish immediately below the dorsal fin. Secondary marks were given to tagged fish: upper caudal and adipose clips for fish caught in shallow (≤30 m) water, and lower caudal and adipose clips for fish caught in deep (>30 m) water. Fish <170 mm FL were marked with only an upper or lower caudal clip.

ESTIMATES OF SHALLOW -WATER ABUNDANCE

Abundance of brook trout in the shallow water of Green Lake was estimated with a Petersen mark-recapture experiment (Seber 1982). Assumptions of the experiment were: *(a)* the population was closed (no mortality, immigration, emigration or recruitment of brook trout during the experiment); *(b)* all brook trout had the same probability of capture during the marking event or the same probability of capture during the recapture event or marked and unmarked brook trout mixed completely between the marking and recapture events; *(c)* marking of brook trout did not affect their probability of capture in the recapture event; *(d)* brook trout did not lose their mark between events; and *(e)* all marked brook trout were reported when recovered in the recapture event.

The validity of assumption *(a)* was inferred, because the dam at the lake outlet prevented brook trout movement into Green Lake and emigration

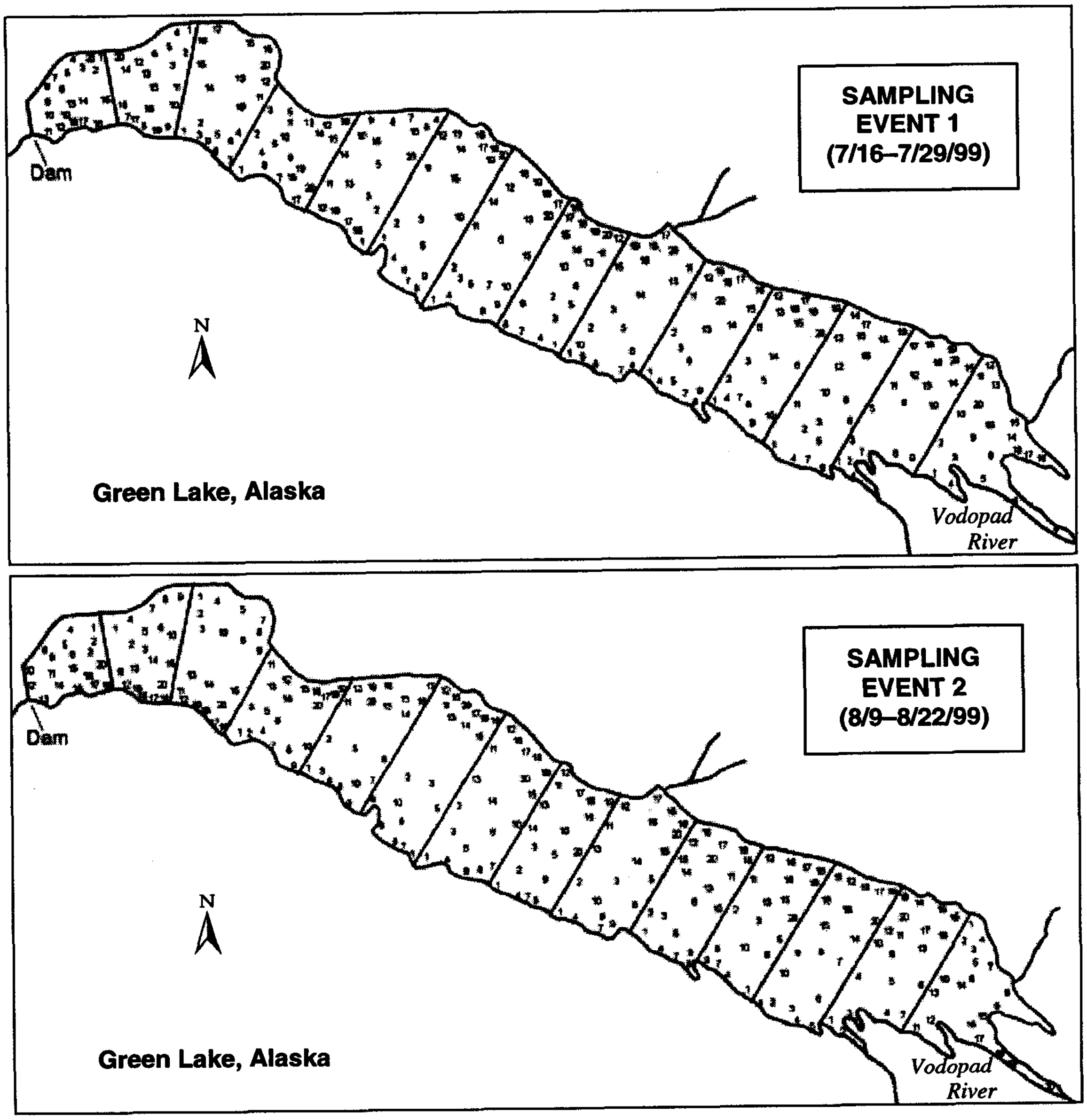

Figure 4.–Trap set locations at Green Lake in 1999 during sampling events 1 and 2.

was unlikely. Mortality and growth, which may contribute to the violation of assumption *(a)*, were assumed negligible because of the short duration of the experiment (two 14-day events). The validity of assumptions *(b)* and *(c)* was evaluated by a series of chi-square and Kolmogorov-Smirnov (K–S) statistical tests designed to detect unequal catchability by area and size of fish (Appendix A2). The validity of assumption *(d)* was ensured by double-marking (Floy® tag and finclip) each brook trout during the marking event. The validity of assumption *(e)* was ensured by a thorough examination of fins for finclips and recording Floy tag numbers for all brook trout.

If all assumptions were met, the abundance in shallow (<30 m) water was estimated as

$$\hat{N}_{Shallow} = \frac{(C+1)(M+1)}{R+1} - 1 \qquad (1)$$

$$V[\hat{N}_{Shallow}] = \frac{(M+1)(C+1)(M-R)(C-R)}{(R+1)^2(R+2)} \qquad (2)$$

where

$\hat{N}_{Shallow}$ = estimated abundance of brook trout in shallow water

M = number of fish marked during the first sampling event in shallow water

C = number of fish examined during the second sampling event in shallow water, and

R = number of fish captured during the second sampling event with marks from the first sampling event.

ESTIMATES OF DEEPWATER ABUNDANCE

The relationship between catch per unit effort (CPUE) and abundance was used to estimate the abundance of brook trout in deep water as (from Gulland 1983):

$$CPUE = q\hat{N} \tag{3}$$

$$\therefore \hat{N}_{Deep} = \frac{CPUE}{\hat{q}} \tag{4}$$

where

CPUE = average CPUE of brook trout in deep water, and

$\hat{q}$ = estimated catchability of brook trout, calculated using the shallow water data and formula 3.

SIZE COMPOSITION

The brook trout caught in shallow water (<30 m) were significantly smaller than those caught in deep water (t = 2.67, df = 306, p = 0.008). Therefore, the proportion of the population ≥170 mm FL in length class j and its variance was estimated as a stratified binomial proportion (Cochran 1977) by

$$\hat{p}_k = \sum_{i=1}^{j} \frac{N_i}{\hat{N}} \hat{p}_{ik}, \tag{5}$$

and

$$\hat{V}[\hat{p}_k] \approx \sum_{i=1}^{j} (\hat{p}_{ik} - \hat{p}_k)^2 \frac{\hat{V}[\hat{N}_i]}{\hat{N}^2} + \sum_{i=1}^{j} \left(\frac{\hat{N}_i}{\hat{N}}\right)^2 \hat{V}[\hat{p}_{ik}] \tag{6}$$

where

$\hat{N}_i$ = the abundance of brook trout in depth i;

$\hat{N}$ = total abundance of brook trout, and

$\hat{p}_{ik}$ = the estimated proportion of brook trout in depth i that were in length group k.

CATCH PER UNIT EFFORT

Mean catch per unit effort (CPUE) data by gear type are useful for planning and for comparing relative catch rates at different lakes and/or times of the year. Mean CPUE was calculated as follows:

$$cpue = \frac{\sum_{t=1}^{n_t} catch}{\sum_{t=1}^{n_t} effort} \tag{7}$$

$$V[cpue] = \frac{\sum_{t=1}^{n_t} (catch_t - effort_t * cpue)^2}{\bar{e}^2 * n_t(n_t - 1)} \tag{8}$$

The final data file (GREEN LAKE 1999 DATA.XLS) is archived at ADF&G offices in Sitka and Anchorage (Sport Fish Division, Research and Technical Services section).

RESULTS

Of 548 brook trout marked in shallow water, only 1 was recaptured in deep water. Conversely, of 17 fish marked in deep water, none were recaptured in shallow water. Because few fish were captured in deep water and little mixing between deep and shallow areas was observed, we could not show that the probability of capture was equal between deep and shallow areas. Therefore, we estimated abundance separately for shallow and deep areas of the lake.

SHALLOW-WATER ABUNDANCE

The estimated abundance in 1999 of brook trout ≥170 mm FL in shallow (≤30 m) waters of Green Lake was 3,013 (SE = 537). During the first sampling event, 257 trout ≥170 mm FL were marked and released alive. During the second event, 291 unique brook trout ≥170 mm FL were

Table 1.–**Probability of recapture of brook trout by location** (one of the tests of assumptions needed for the closed population abundance estimator) **at Green Lake, 1999.**

Lake areas	Total marked	Recaptured? No	Recaptured? Yes	Probability of recapture	χ^2	P-value
1–2	88	77	11	0.125	3.013	0.376
3–6	38	36	2	0.052		
7–12	43	40	3	0.069		
13–14	122	114	8	0.065		
Total	291	267	24			

examined, 24 of which bore marks. No tag loss was observed. Nine brook trout were inadvertently killed (8 original captures and 1 recapture).

The length distributions of brook trout captured during the first event and recaptured during the second event were not significantly different (K–S test, $D_{max} = 0.127$, $P = 0.871$; Figure 5, top). There was a difference between length distributions of brook trout captured during the first event and those captured during the second event (K–S test, $D_{max} = 0.175$, $P < 0.001$; Figure 5, bottom). The outcome of these 2 tests indicated size-selectivity during the first event and an unstratified abundance estimator was used. However, only those fish captured during the second sampling event were used to estimate mean length composition (Bernard and Hansen 1992, Appendix A2).

The probability of recapture was not significantly different among the different areas of the lake ($\chi^2 = 3.013$, $P = 0.376$; Table 1), and 38% of the recaptured fish were recaptured outside the area where they were marked (Table 2). These two results indicate that mixing was sufficient to minimize bias in the estimate.

Although there was a significant difference in the length distribution of captured fish between the two gear types (K–S test, $D_{max} = 0.396$, $P < 0.001$; Figure 6), the effort by gear type was uniform throughout the lake during both events. The probability of recapture was not significantly different between gear types ($\chi^2 = 1.803$, $P = 0.179$; Table 3), and 21% of the recaptured fish were recaptured by gear different from that used for marking (Table 4). These results indicated no need to stratify by gear type; fish captured by both

Table 2.–Mixing of brook trout recaptured by location at Green Lake, 1999.

Mark areas	Number recaptures by location 1–2	3–6	7–12	13–14	Total
1-2	7	0	0	1	8
3-6	2	1	1	0	4
7-12	1	1	2	2	6
13-14	1	0	0	5	6
Total	11	2	3	8	24

gear types were therefore used in the abundance estimate.

DEEPWATER ABUNDANCE

The estimated CPUE was 14 times greater in traps set in shallow water than in traps set in deep (>30 m) water (Table 5). Deepwater abundance was calculated to be 216 (SE = 722) (Table 6). Because few fish were captured or recaptured in deep water, the standard error and relative precision were large (RP = 550%). Although 95% of all hoop trap caught fish were captured in depths ≤27 m (Figure 7), 7% of the population resided in deep water based on the difference in CPUE. Thus, we failed to reject our hypothesis that 5% or more of the brook trout population ≥170 mm FL resided in the deep (>30 m) water of Green Lake.

The total abundance of brook trout ≥170 mm FL in Green Lake in 1999 was estimated to be 3,229 (SE = 900, RP = 46%).

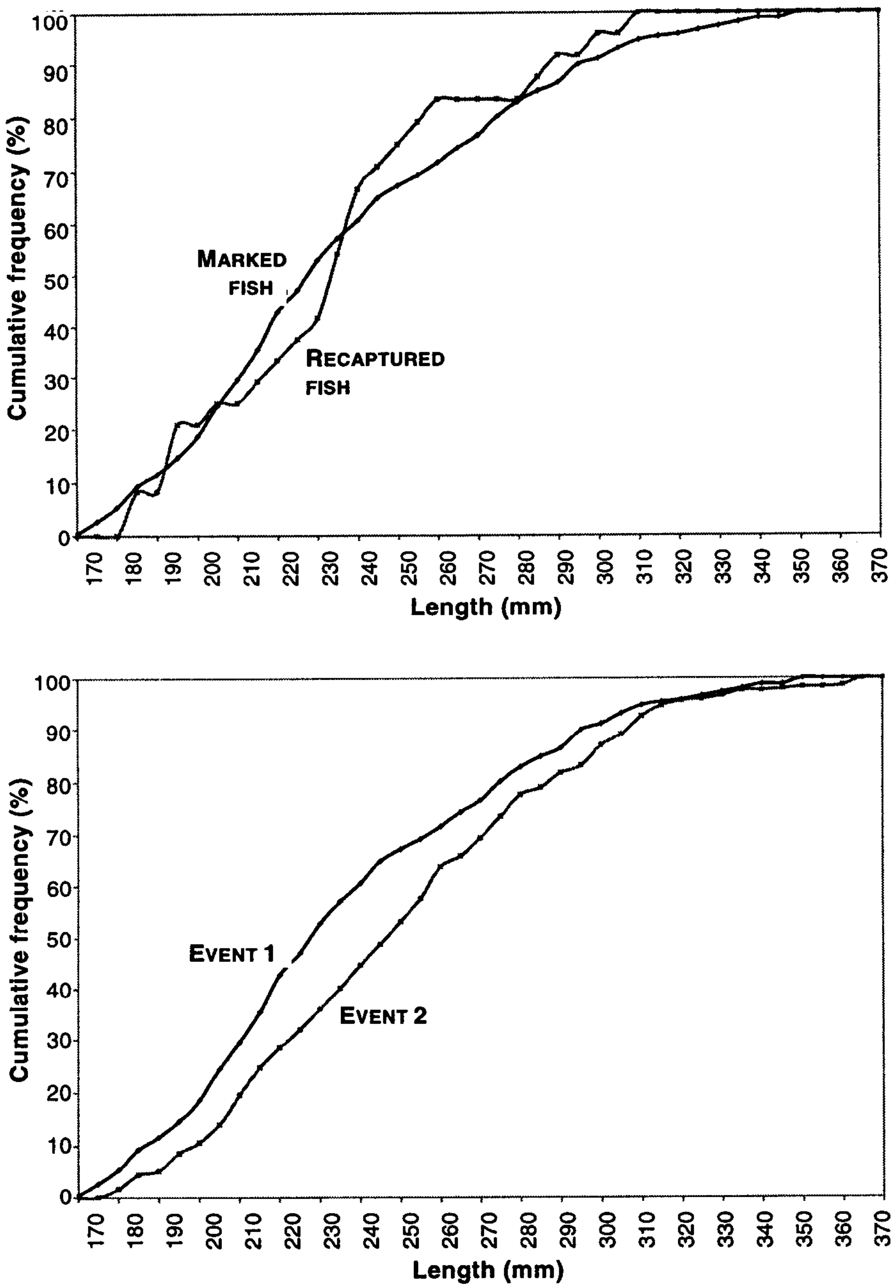

Figure 5.–Cumulative distributions of lengths of brook trout marked in event 1 versus lengths of brook trout recaptured in event 2 (top) **and examined during event 2** (bottom),**Green Lake, 1999.**

SIZE COMPOSITION

Because there was size-selectivity during the first event, only those fish captured during the second event were used to estimate length composition. Fish captured with hook-and-line gear (mean FL = 267 mm, SE = 3.5, n = 142) were larger than fish captured with traps (mean FL = 236 mm, SE = 1.9, n = 406) (Figure 6). Because mixing was demonstrated between gear types, we pooled all sampling data for original captures during the second event to estimate length composition of the population.

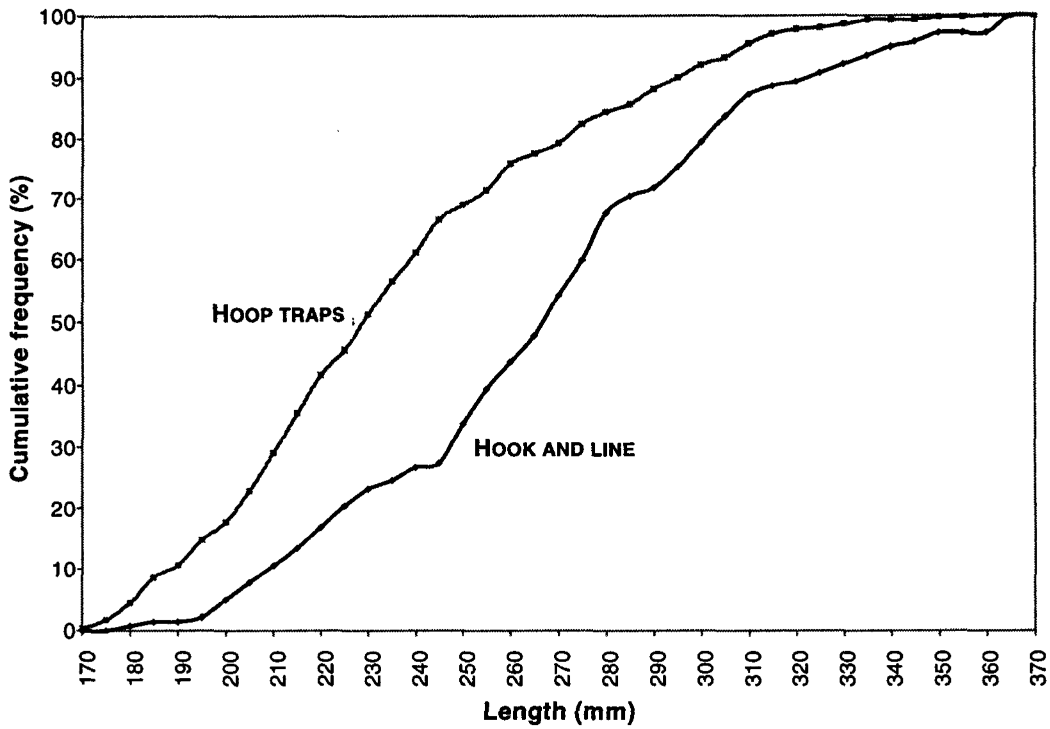

Figure 6.–Cumulative distributions of brook trout captured with hoop traps versus hook-and-line at Green Lake in 1999.

Mean length was 250 mm FL (SE = 2.4). Length composition of brook trout ≥170 mm FL consisted predominantly (64%) of fish 200–279 mm FL (Table 7 and Figure 8). Because fish <200 mm were represented in smaller numbers than fish ≥200 mm, 200 mm appeared to be the size at which fish were fully recruited to both hoop traps and hook-and-line.

The lake was at spill level for most of the project duration (Appendix A3). For the remainder (July 16–20), lake elevation was within 10 cm of spill level.

DISCUSSION

Differences in methods prevent a direct comparison of the estimated abundance of 3,229 (SE = 900) brook trout ≥170 mm FL in Green Lake with other brook trout population estimates conducted in Southeast Alaska. The 1979 Green Lake study was conducted using similar capture gear, but the population estimate of 1,442 included all fish captured (i.e., no lower size limit). Population estimates conducted in Salmon Creek Reservoir and Thimbleberry Lake also

Table 3.–Probability of recapture of brook trout in Green Lake by gear type.

Gear type	Total marked	Recaptured? No	Recaptured? Yes	Probability of recapture	χ^2	P-value
Hook & line	83	79	4	0.048	1.803	0.179
Hoop trap	208	188	20	0.096		
Total	291	267	24			

Table 4.–Mixing of brook trout recaptured at Green Lake, 1999, by gear type.

	Number recaptures by gear				
Mark gear	Hook & line	Hoop trap	Total	χ^2	P-value
Hook & line	1	2	3	0.686	0.408
Hoop trap	3	18	21		
Total	4	20	24		

encompassed a larger proportion of the population, because all fish captured were included. In prior experiments at Salmon Creek Reservoir and Green Lake, trap sets were concentrated in shallow areas, which may also have contributed to bias. Nevertheless, the abundance in Green Lake appears to be relatively large, compared to other brook trout populations in Southeast Alaska and compared to the population in Green Lake before construction of the dam. As in this study, Schmidt (1977) found CPUE for hoop traps set in shallow (<6 m) areas (1.40 fish/trap, n = 218) to be higher than CPUE in deep areas (0.82 fish/trap, n = 122).

One goal of this project was to investigate potential impacts on brook trout in Green Lake from the 1998 introduction of chinook salmon. Impacts of introducing coho salmon into previously landlocked populations of cutthroat trout have been studied in three locations in Southeast Alaska. In the Slippery Creek drainage, an Alaskan steeppass was installed in 1988, which allowed anadromous fish to immigrate to Slippery Lake, and coho salmon fry were stocked between 1987 and 1990. Mean fork length of cutthroat trout declined from 205 mm in 1988 to 187 mm in 1990, but the abundance of the lake population of cutthroat trout appeared unchanged (Wright et al. 1997). At Margaret Lake, an Alaskan steeppass was installed in 1990, sockeye salmon fry were stocked from 1988 through 1994, and summer-run coho salmon were stocked in 1991. Assessment studies indicated an inverse relationship between abundance of coho salmon and cutthroat trout, and a lower mean length of cutthroat trout suggested a density-dependent response to coho salmon (Bryant et al. 1994). Whereas the results of these studies do not show causal relationships, they do indicate that competition appeared greatest between cutthroat trout <140 mm and coho salmon.

A baseline population study was also recently completed in Neck Lake on Prince of Wales Island, where hatchery coho salmon are stocked in a lake with a resident cutthroat trout population (Harding et al. 1999). As in this study, no immediate impacts were found, but the authors hypothesized that impacts might appear after several more years. It is probable that continued stocking would have greater impacts on a resident trout population than in Green Lake, where the release was a one-time occurrence. The chinook salmon released are expected to die within 2–3 years; the only probable continuing impacts on the brook trout population would be related to the presence of net pens (and fish foods or wastes). CPUE for chinook salmon from this study is provided (Appendix A4) as a potential index of chinook abundance for comparison with future studies.

Table 5.–Trap and hook-and-line effort, catch, and catch per unit effort (CPUE) for brook trout in Green Lake, 1999.

Gear	Depth	Total catch	Total effort	Mean catch	Mean effort	CPUE	SE	Sample size
Hoop traps	Shallow	413	342.19	1.16	0.96	1.21	0.20	355
	Deep	17	196.66	0.08	0.96	0.09	0.07	205
Hook & line	Shallow	158	62.97	2.82	1.12	2.51	0.44	56

Table 6.–Estimated abundance of brook trout in deep water at Green Lake in 1999 based on hoop trap CPUE and catchability.

Depth		Estimate	SE	Relative precision
Shallow	CPUE	1.206	0.1965	
	Estimated abundance	3,013	537	29
	Estimated catchability	0.0004	0.0001	
Deep	CPUE	0.086	0.0373	
	Estimated abundance	216	722	550
	Estimated catchability	0.0004	0.0001	

The results of our study shed little light on the potential impact to brook trout caused by the large number of chinook salmon fry released into Green Lake in 1998. The chinook release provided a large added potential food source for brook trout. During this study, crew member observations of salmon in the mouths of brook trout captured in hoop traps and by hook-and-line confirmed that brook trout preyed on chinook salmon. However, the extent to which capture gear influenced feeding behavior may be significant; this aspect was not examined. Hughes (1994) found benthic mollusks and insect larvae to be the primary prey of 31 brook trout sampled for stomach content analysis in 1979; fish remains were found in only one brook trout examined. Hughes (1994) and Arnold et al. (*unpublished*) also noted the condition of brook trout to be good (K = 0.94 and 0.92, respectively, before and after dam construction). These studies did not indicate food availability as limited. Length composition of the 1979 and 1999 populations are difficult to compare because of bias associated with the 1979 estimate. Fish captured in 1979 were smaller (TL = 65 mm) than in 1999 (FL = 110 mm), but fish are not fully recruited to the combination of hoop trap and hook-and-line gear until 200 mm FL. Sizes of the largest fish observed in 1979 (TL = 378 mm) and in 1999 (FL = 364 mm) were comparable.

The primary benefit of this study is its use as a baseline for future stock assessment of brook trout. If potential adverse impacts caused by chinook salmon competition or predation are

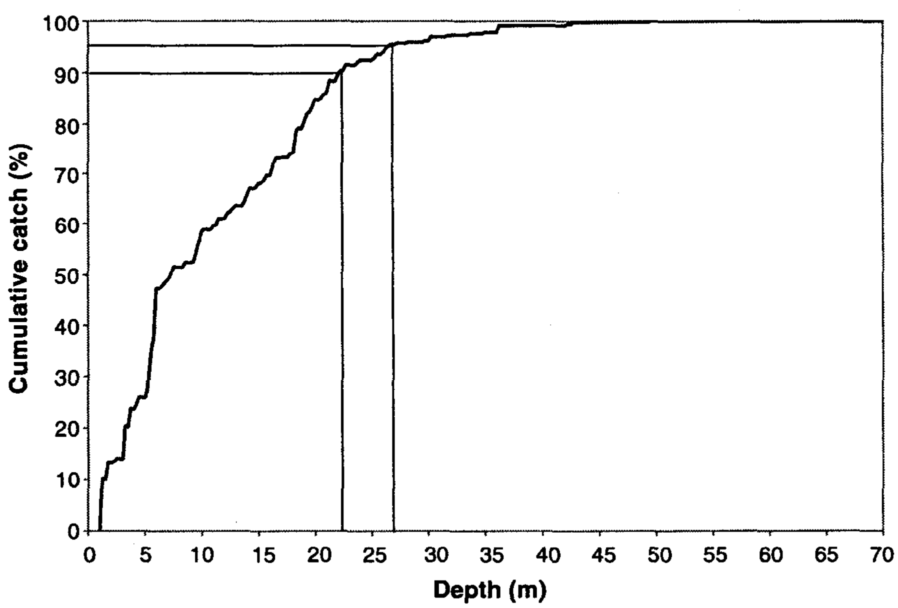

Figure 7.–Cumulative catch distribution of brook trout at depth in Green Lake, 1999. Overall, 95% of hoop trap caught fish were captured in water <27 m deep and 90% were caught in water <23 m.

Table 7.–Estimated length composition of brook trout ≥170 mm FL at Green Lake in 1999.

Length category (mm)	Sample size n_j	Proportion $\hat{p}_j$	SE	Estimated abundance $\hat{N}_j$	SE
170-179	2	0.006	0.005	21	15
180-189	14	0.051	0.025	165	53
190-199	15	0.054	0.025	176	55
200-209	26	0.083	0.016	269	69
210-219	27	0.093	0.021	300	76
220-229	21	0.067	0.014	217	59
230-239	24	0.077	0.015	248	65
240-249	25	0.080	0.015	259	67
250-259	30	0.103	0.021	331	81
260-269	18	0.058	0.013	186	53
270-279	24	0.083	0.022	269	70
280-289	17	0.055	0.013	176	51
290-299	13	0.054	0.054	176	167
300-309	17	0.055	0.013	176	51
310-319	10	0.032	0.010	104	37
320-329	4	0.013	0.006	41	22
330-339	4	0.013	0.006	41	22
340-349	2	0.006	0.005	21	15
350-359	1	0.003	0.003	10	10
360-369	4	0.013	0.006	41	22
Total	298	0.999		3,227	

greatest for small brook trout in Green Lake, as indicated for cutthroat trout in Slippery Creek and Margaret Lake, effects may be greatest on fish spawned as early as the fall of 1997. This brood comprised age-0 fish in 1998, when chinook salmon were released. Hughes (1994) estimated the mean length for age-2 and age-3 fish to be 169 and 232 mm TL, respectively, and Arnold et al. (*unpublished*) estimated the mean length for the same ages to be 71 mm and 247 mm FL. Because brook trout do not appear to be fully recruited to the combination of hoop traps and hook-and-line used in this study until they reach 200 mm FL, potential impacts to age-0 fish would not be detectable for at least three years. We therefore recommend another abundance estimate in 2002, when both the 1997 and 1998 year classes (i.e., age-1 and age-0 in 1998) will be recruited to capture gear.

We hypothesized that 5% of the population resided in water deeper than 30 m, but we estimated that 7% of the brook trout population resided in water >30 m and 5% resided in water >35 m. In light of these results, and considering that mark-recapture studies for cutthroat trout are routinely limited to lake depths ≤35 m, limiting mark-recapture studies for brook trout to depths ≤35 m should include at least 95% of the population.

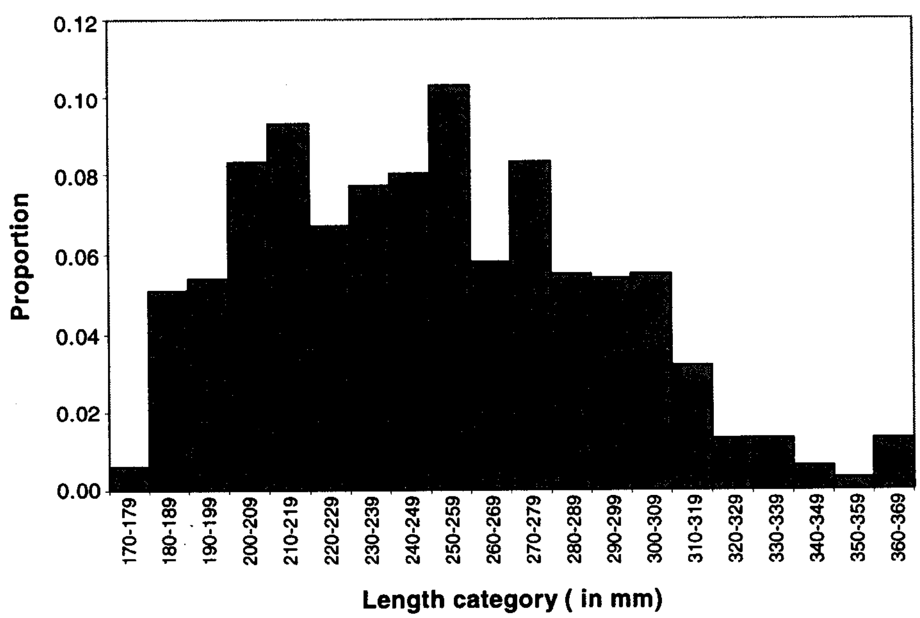

Figure 8.–Estimated length composition of brook trout ≥170 mm FL at Green Lake, 1999.

ACKNOWLEDGMENTS

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APPENDIX A

Appendix A1.–Stocking history of lakes in Southeast Alaska with known populations of brook trout (ADF&G unpublished data).

		Management	Stocking history		
Area/lake		area	Date	Number	Source
Northern Southeast					
	Annex	Juneau	1917		Leadville, Co
	Deep	Sitka	1931	2,100	Yes Bay
	Devil's Punch Bowl	Haines/Skagway	1989	400	Upper Dewey
	Dorothy		1931	7,000	Yes Bay
	Green	Sitka	1932		Yes Bay
	Heart	Sitka	1928	6,800	Yes Bay
			1932	6,800	Yes Bay
	Long	Sitka	1931	1,600	Yes Bay
	Lower Dewey	Haines/Skagway	1920	20,000	
			1926	5,000	
			1927	2,800	
			1932	1,000	Yes Bay
			1936	2,800	
			1937		
			1939	10,000	
	Rustabach	Haines/Skagway	1932	1,700	
	Salmon Creek Reservoir	Juneau	1917		Leadville, Co
			1927	13,157	
	Thimbleberry	Sitka	1928	6,800	Yes Bay
			1932		Glenallen
	Upper Dewey	Haines/Skagway	1920	25,000	
Southern Southeast					
	Bugge		1931	1,500	Yes Bay
	Claude	Ketchikan	1931	1,600	Yes Bay
	Connell[a]	Ketchikan			
	Crystal	Petersburg	1931		Yes Bay
	Grace	Ketchikan	1931	500	Yes Bay
			1932	7,625	Yes Bay
	Ketchikan	Ketchikan	1931	5,000	Yes Bay
	Nellie	Ketchikan	1931		Yes Bay
	Perseverance	Ketchikan	1931	2,000	Yes Bay
			1932	2,500	Yes Bay
	Ward[a]	Ketchikan			
	Whitman	Ketchikan	1931	2,500	Yes Bay

[a] Connell and Ward lakes were naturally populated by migratory fish from Perseverance Lake.

Appendix A2.–Detection of size-selective sampling (from Bernard and Hansen 1992).

Result of hypothesis test on lengths of fish CAPTURED during the first event and RECAPTURED during the second event	Result of hypothesis test on lengths of fish CAPTURED during the first event and CAPTURED during the second event.

Case I: **Accept H_o** **Accept H_o**

There is no size-selectivity during either sampling event.

Case II: **Accept H_o** **Reject H_o**

There is no size-selectivity during the second sampling event but there is during the first.

Case III: **Reject H_o** **Accept H_o**

There is size-selectivity during both sampling events.

Case IV: **Reject H_o** **Reject H_o**

There is size-selectivity during the second sampling event; the status of size-selectivity during the first event is unknown.

Case I: Calculate one unstratified abundance estimate, and pool lengths, sexes, and ages from both sampling events to improve precision of proportions in estimates of composition.
Case II: Calculate one unstratified abundance estimate, and only use lengths, sexes, and ages from the second sampling event to estimate proportions in compositions.
Case III: Completely stratify both sampling events, and estimate abundance for each stratum. Add abundance estimates across strata to get a single estimate for the population. Pool lengths, ages, and sexes from both sampling events to improve precision of proportions in estimates of composition, and apply formulae to correct for size bias to the pooled data.
Case IV: Completely stratify both sampling events and estimate abundance for each stratum. Add abundance estimates across strata to get a single estimate for the population. Use lengths, ages, and sexes from only the second sampling event to estimate proportions in compositions, and apply formulae to correct for size bias to the data from the second event.

Whenever the results of the hypothesis tests indicate that there has been size-selective sampling (Case III or IV), there is still a chance that the bias in estimates of abundance from this phenomenon is negligible. Produce a second estimate of abundance by not stratifying the data as recommended above. If the two estimates (stratified and unbiased vs. biased and unstratified) are dissimilar, the bias is meaningful, the stratified estimate should be used, and data on compositions should be analyzed as described above for Cases III or IV. However, if the two estimates of abundance are similar, the bias is negligible in the UNSTRATIFIED estimate, and analysis can proceed as if there were no size-selective sampling during the second event (Cases I or II).

Appendix A3.–Water temperatures and lake surface levels at Green Lake, July 16–August 22, 1999.

	Water temp	Lake level
Date	^0C	(inches)
16-Jul	12.3	392.0
17-Jul	11.9	393.0
18-Jul	12.6	393.5
19-Jul	12.9	394.0
20-Jul	13.0	394.5
21-Jul	13.1	395.0
22-Jul	13.2	395.0
23-Jul	13.4	395.5
24-Jul	13.3	395.5
25-Jul	13.3	395.5
26-Jul	13.7	395.5
27-Jul	13.8	395.4
28-Jul	13.4	395.9
29-Jul	13.4	396.0
30-Jul	13.5	396.0
31-Jul	13.9	395.8
1-Aug	14.7	396.0
2-Aug	15.7	396.0
3-Aug	14.0	396.0
4-Aug	14.3	396.0
5-Aug	14.9	396.0
6-Aug	14.6	396.0
7-Aug	15.2	396.0
8-Aug	15.5	395.5
9-Aug	16.5	395.5
10-Aug	16.1	395.5
11-Aug	16.1	395.5
12-Aug	15.8	395.5
13-Aug	15.6	395.5
14-Aug	15.8	395.5
15-Aug	15.5	395.5
16-Aug	15.3	395.8
17-Aug	15.4	395.8
18-Aug	15.4	395.8
19-Aug	15.1	395.6
20-Aug	14.7	395.6
21-Aug	14.6	395.5
22-Aug	14.4	395.7

Appendix A4.–Trap and hook-and-line effort, catch, and catch per unit effort (CPUE) for chinook salmon in Green Lake, 1999.

Gear	Depth	Total catch	Total effort	Mean catch	Mean effort	CPUE	SE	Sample size
Hoop traps	Shallow	79	342.19	0.22	0.96	0.23	0.05	355
	Deep	0	196.66	0.00	0.96	0.00	0.07	205
Hook & line	Shallow	157	62.97	2.80	1.12	2.49	0.51	56